NEHRP FINAL TECHNICAL REPORT

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Title: 3-D FAULT GEOMETRY ALONG THE HAYWARD-RODGERS CREEK-MA' ACAMA FAULT CORRIDOR

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ABSTRACT:

Although the general process by which the San Andreas Plate boundary (SAPB) forms in response to the fundamental plate tectonic change as the Mendocino Triple Junction migrates along the western margin of North America is well known, the details of the processes by which the specific major faults, which comprise the plate boundary, form is less well understood. Although the San Andreas Fault is typically invoked as the main plate boundary structure, it is clear in Northern California that other major faults play an equal or greater role. In particular, the fault corridor running from nascent to mature of the Maacama-Rodgers Creek-Hayward-Calaveras-San Andreas represents the primary locus of plate boundary deformation on a lithospheric scale. The Hayward Fault sits in a key transitional position along the corridor as it represents the first fully mature segment of the plate boundary along its evolutionary corridor. The mechanical and kinematic behavior of the Hayward Fault, particularly in comparison with the less mature segments to the north, provide insight into both the processes of plate boundary development and the physical fault zone characteristics that are imprinted on the fault during its evolution. For example, characteristic behavior observed on the Hayward Fault, such as substantial fault creep, which also occurs along segments of the Maacama Fault, appears to be an early acquired attribute of the system. Such fault creep behavior is enabled by localized shear beneath the fault, implying that a localized SAPB system, on a lithospheric scale, is well established along the corridor after just a few million years of post-MTJ tectonics, even in regions (such as the central and northern Maacama Faults) where multiple surface strands are currently active. I

In this project we have focused on two specific aspects of the fault zone behavior within the Hayward-Rodgers Creek-Maacama Fault Corridor: (1) The extent and nature of creeping fault segments, and their relationship to fault displacement histories; and (2) the geometry of the fault system in its northern (young) extent. Basic results of the research are:

1. Fault slip rates and offsets along the Hayward-Calaveras system through the San Francisco region are discrepant with fault slip further to the north along the Rodgers Creek - Maacama segments. Mendocino triple junction processes are assumed to account for much of this discrepancy. (Fig. 1)
2. Behavior of creeping faults can be directly linked to segments that have a history of interaction with the passage of the Bay Area Block and most importantly the migration of the crustal triple junction at the join of the Central San Andreas - Santa Cruz Mtn San Andreas and East Bay faults (Hayward and Calaveras) - what we have termed the San Juan Batista Crustal triple junction.(Fig. 2)
3. Fault segments that creep at full fault slip rate are associated with passage of the SJB triple junction, while faults adjacent to the migrating Bay Block (but north of the SJB triple junction) creep, but at rates less than full fault slip. (Fig. 3)
4. Faults at the northern end (young end) of the system show a complex geometry in which the observed surface creeping fault (e.g. Maacama Fault through Willits) is offset from the main seismicity trend. Recently obtained LiDAR imagery through the region shows an active fault trace associated with the seismicity. The fault slip rates are uncertain for this newly identified fault.

The current understanding of fault offsets along this corridor are shown in Figures 1 and 2. The substantial fault offset in the Bay Area and the very abrupt decrease in offset moving to the north remains one of the major discrepancies in our understanding of the fault system. How the mismatch in fault skip is accommodated is not clear, but likely reflects processes associated with the Furlong and Gover's proposed Mendocino Crustal Conveyor model of Mendocino triple junction tectonics.

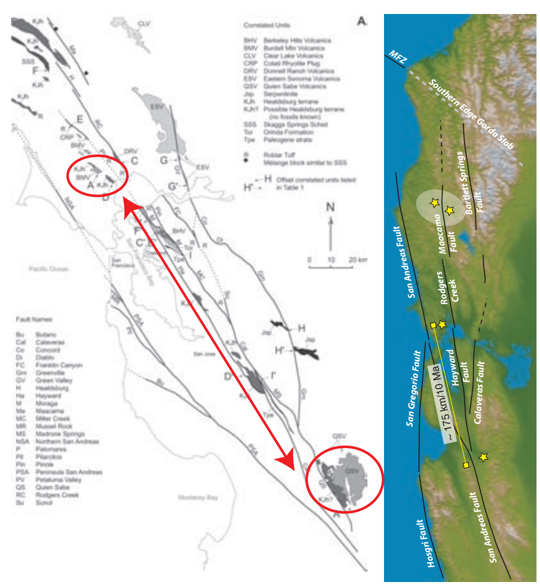


Figure 1. Basic fault displacement relations for faults within the San Andreas plate boundary system in northern California. (left) Correlations between volcanic centers used to define offset along the Hayward Fault system. (right) Further north along same fault corridor, fault offset diminishes to only a few km at maximum. This fault slip discrepancy remains, but is likely at least partially accommodated by crustal deformation processes associated with Mendocino triple junction migration.

When one looks particularly at the impact of migration of the San Juan Batista crustal triple junction (Fig. 2), we see that regions of the fault corridor that have experienced passage of the crustal triple junction define those regions that also presently undergo fault creep at essentially the full fault slip rate (Fig. 3).

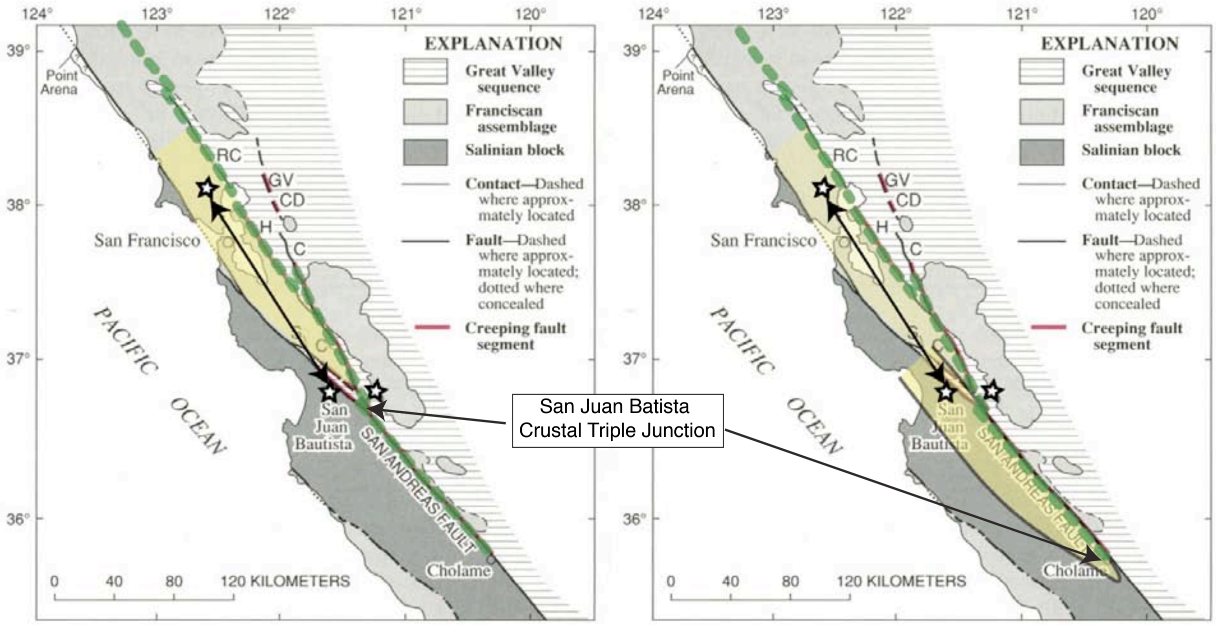
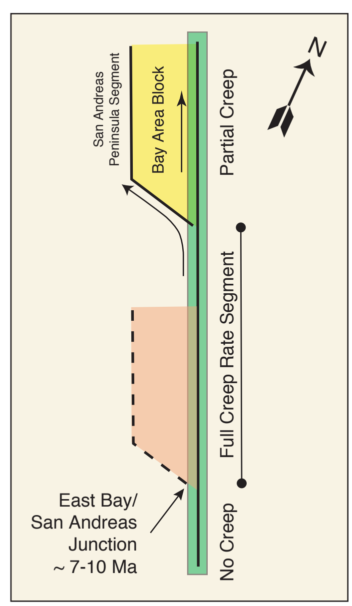


Figure 2. Offset along the Hayward Fault system defines extent of displacement of the Bay Area Block (shaded region). Bay Area Block formed as a result of formation of the transfer fault (present-day Santa Cruz Mtn segment of the San Andreas system) linking the main plate boundary structure to the coastal fault. The resulting migration of the 'crustal triple junction' (San Juan Batista (SJB) crustal triple junction) produced a deformational history for the fault zone that differs from regions north and south.

Figure 3. Relationship between regions associated with migration of the SJB Crustal triple junction and present day fault creep properties. Regions traversed by the crustal triple junction show creep at essentially full fault-slip rates, while regions adjacent to migrating Bay Area Block, creep but at rates less than total fault slip.



Although the causative mechanism of this process is not clear, the correlation between kinematics and dynamics implies an important deformational behavior as the Bay Area block migrates northward along the fault system. Detailed analysis of seismicity at the current position of the crustal triple junction may provide a key to understanding what deformation drives this change in fault zone behavior.

Finally in this research project, we have investigated the geometric behavior of faults within the corridor in the early stages of fault development. The focus has been on the northern Maacama Fault from Ukiah north to Laytonville (at which point, it becomes obscured). Using precisely relocated seismicity along the fault corridor (relocated using a wave-form cross-correlation double-difference approach) we have determined that along the Willits segment of the Maacama Fault (Fig 4), the well expressed surface trace of the creeping fault is not associated with the main swath of crustal seismicity. Rather that swath is approximately 10 km to the east along the east side of Little Lake Valley. This earthquake trend is consistent with plate motions and fault location in the Ukiah region and indicates that within the crust the main trace appears to continue along this structure. A fundamental question remains as to the earthquake potential of the two fault strands. Recently obtained LiDAR imagery along the east side of Little Lake Valley shows a fault strand that appears to be active, although no information on its slip rate of seismic potential yet exists.

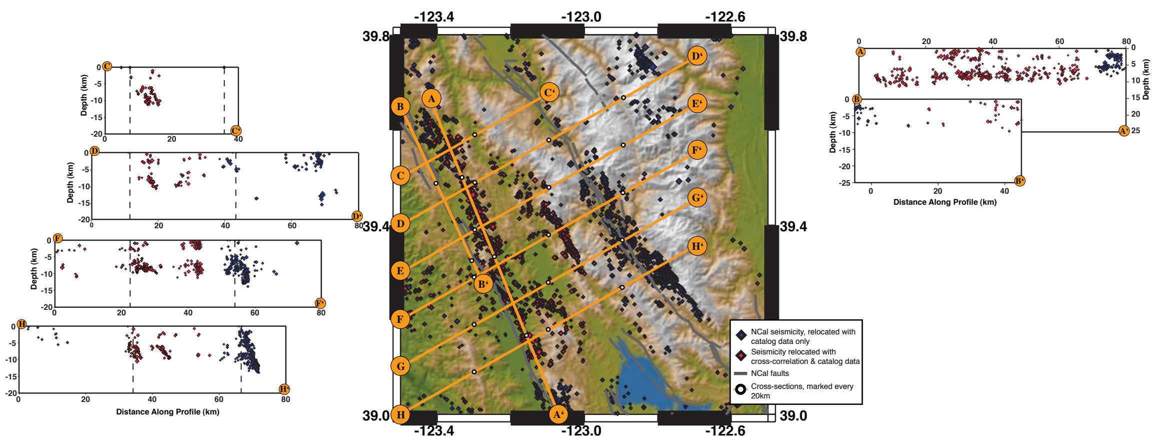


Figure 4. Fault zone structure along northern Maacama Fault segment - northern limit of well-defined faulting within the corridor. Relocated seismicity (waveform cross correlation, double-difference relocations) indicate that the seismically active strand of the Maacama is offset to the east from the observed, creeping trace through Willits.

Bibliography of Publications Under this Grant:

Paper partially supported by this grant:

Hayes, G.P., and **Furlong, K.P**., 2007. Abrupt Changes in Crustal Structure Beneath the Coast Ranges of Northern California - Developing New Techniques in Receiver Function Analysis, *Geophys. J. Int., 170,* 313-336.

Paper in Press partially supported by this grant:

Johnson, C., **K.P. Furlong**, and E. Kirby, 2009, Integrated geomorphic and geodynamic modeling of a potential blind thrust in the San Francisco Bay area, California, *Tectonophysics* (in press)

Abstracts of work accomplished under this grant:

*Furlong, K.P.; Williams, T., Linking Geodetics and Geodynamics along the northern San Andreas system (solicited), GD08-1MO3O-001, abst. of papers presented at *2007 European Geosciences Union General Assembly*

*Furlong, K.P.; Malservisi, R., Lithospheric controls on fault creep: Insights from the San Andreas fault system, G7/GD15-1TU4O-002, abst. of papers presented at *2007 European Geosciences Union General Assembly*

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